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Cincinnati, Ohio

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by

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INTRODUCTION

An instrument is required to measure continuously environmental levels of airborne radon and thoron as well as beta activity and long-lived alpha emitters. Described below (Figure 1) is an instrument which achieves these requirements by filtering air through a membrane filter in a step wise manner continuously observing the deposited alpha activity of the radon and thoron daughter products. This observed activity is theoretically related to the airborne gaseous radon and thoron [1,2,3].

SAMPLING

Filtration of the air through a membrane filter deposits the radon and thoron decay products on the filter; however, the elements themselves, being gaseous, are not captured. The activity of the radon and thoron daughters is recorded by monitoring at the sampling head, thoron daughter activity being observed after the decay of the radon daughters. Radon and thoron daughters have an alpha half-life of approximately 0.5 and 10.6 hours, respectively. If the gaseous activity of the air remains constant, the alpha activity of the filter will reach 99.6 per cent of equilibrium in 4 hours for radon daughters and in 84 hours for thoron daughters, as indicated in Figure 2. Sampling equilibrium exists when the decay rate equals the rate of deposition for a given concentration of parent gas at a constant sampling rate.

Assuming the decay chains are in secular equilibrium, the activity on the filter (RaA, RaC, and ThC) after an infinite sampling period (sampling equilibrium) will be [3]:

$$\text{Radon Concentration } (pc/M^3) = 6\ A_r / f \qquad (1)$$

$$\text{Thoron Concentration } (pc/M^3 = 0.45\ A_t / f \qquad (2)$$

Where

A is filter activity in dpm

f is flow rate in liters/min.

Since equilibrium of the thoron daughters is not obtained in routine operation, corrections for non-equilibrium sampling and decay before analysis are required.

INSTRUMENT

The instrument (Figure 3) collects the airborne activity on a 1 inch wide nylon mesh reinforced membrane tape filter* in a step-wise movement, the collection time being determined by a 0 - 24 hour timer. At the end of the collection period, the timer stops the air pump and advances the filter tape (Figure 4). After advancing 2 inches, the movement is stopped by index holes in the tape which releases a microswitch and a 5 second time delay allows the filter to be seated before sampling is resumed. An air flow of 0 - 2 cfm through a filter area of 4.5 cm^2 is supplied by a rotary vane pump and controlled with a by-pass valve. The air flow is calibrated by plotting the flow rate

*Millipore Microweb filter

as a function of the manometer reading for a particular type of filter using a calibrated tapered tube orifice meter as the primary flow meter.

Two ZnS(Ag) alpha scintillation detectors monitor the alpha activity on the filter. The ZnS is attached to the multiplier phototube with doubly adhesive cellophane tape. A two channel battery powered transistorized preamplifier (Figure 5), mounted at the detector, is sufficient to drive a scaler or ratemeter with 1/4 volt sensitivity when used with a DuMont 6467 multiplier phototube at 1000 volts. The signal is then supplied to a dual-channel 3 cycle logarithmetic ratemeter, channel 1 having a range of 50 - 50,000 cpm and channel 2 a range of 5 - 5,000 cpm. Greater sensitivity is required on second channel detector for the thoron daughter activity, which is approximately a factor of 10 less than radon daugher activity. The output from the rate meters is recorded on a dual-channel strip-chart recorder.

PROCEDURE

In routine operation the channel 1 detector monitors the filter build-up directly over the sampling port. Activity observed here will be the sum of the radon and thoron daughter products as pictured in Figures 2 and 6. The channel 2 detector can be positioned to observe the filter 1, 2, or 3 sampling cycles after collection. In the position directly after collection, the decay, as shown in Figures 2 and 6,

is recorded. Normally the timer is set to advance the filter only when it is apparent that the thoron daughter activity is interfering with the radon daughter products. The thoron daughter activity, observed after the decay of the radon daughter products and corrected for decay and non-equilibrium sampling conditions with the factor from Figure 7, is subtracted from the radon daughter activity.

When the counting efficiency is determined by comparison with an internal proportional counter, the airborne radon and thoron concentrations can be calculated from equations 1 and 2. For these calculations, the membrane filter is assumed to have 100 per cent collection efficiency[5,6] and no self absorption[7] and the background from the alpha detectors (less than 1 cpm) is considered insignificant.

Information concerning long-lived emitters can be obtained by monitoring after the decay of the thoron products or with less delay from the thoron daughter decay curve[4]. In a similar manner, the filter can be monitored for long-lived beta activity with the use of a beta scintillation detector.

APPLICATION

A field version of this instrument is now under construction. In this unit, the ratemeters and strip-chart recorders are replaced with a dual-channel magnetic tape recorder; thus, the tapes from several samplers can be returned to a central facility where they can be analyzed on the ratemeters with a high speed play back.

ACKNOWLEDGEMENTS

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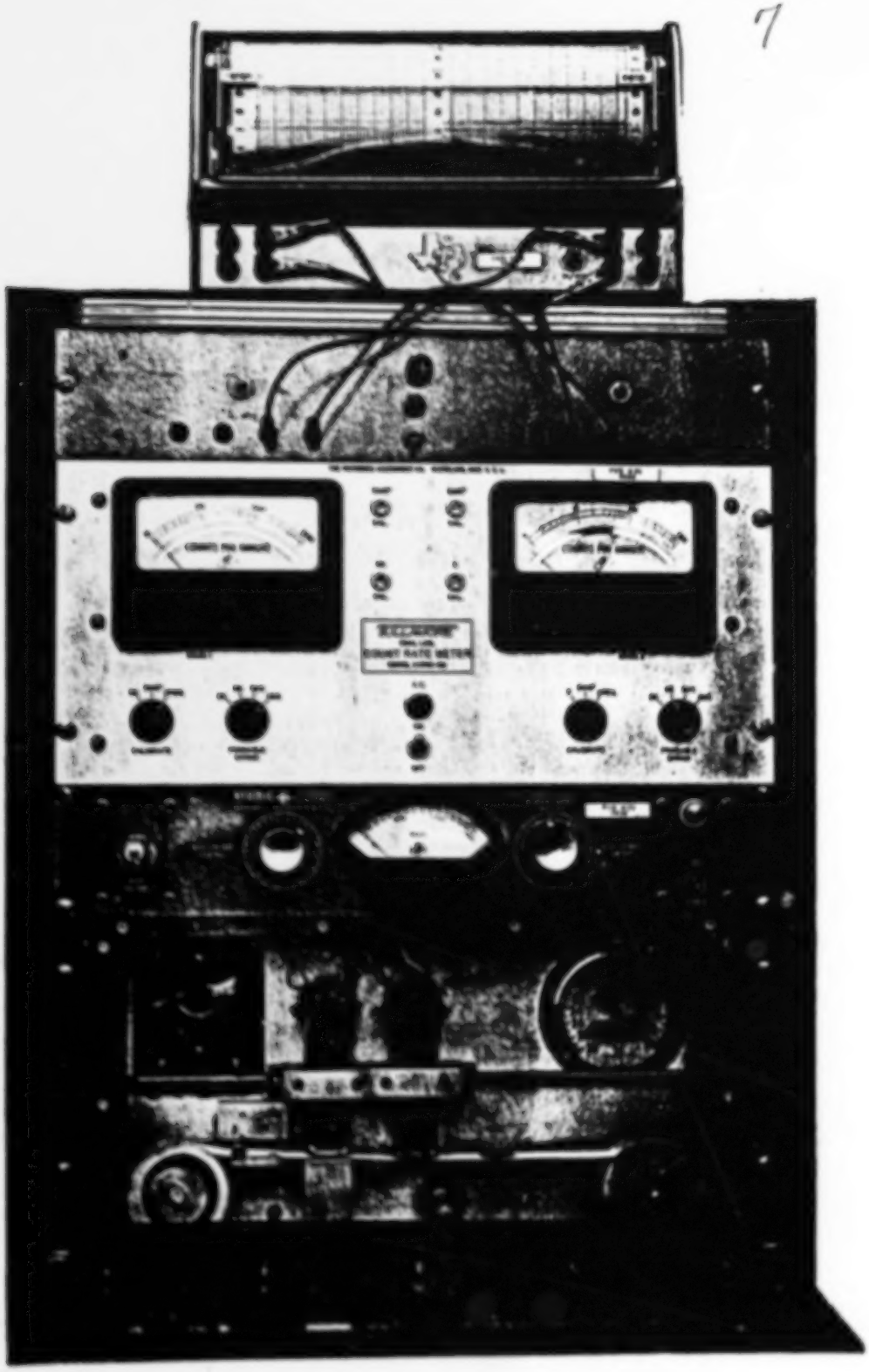

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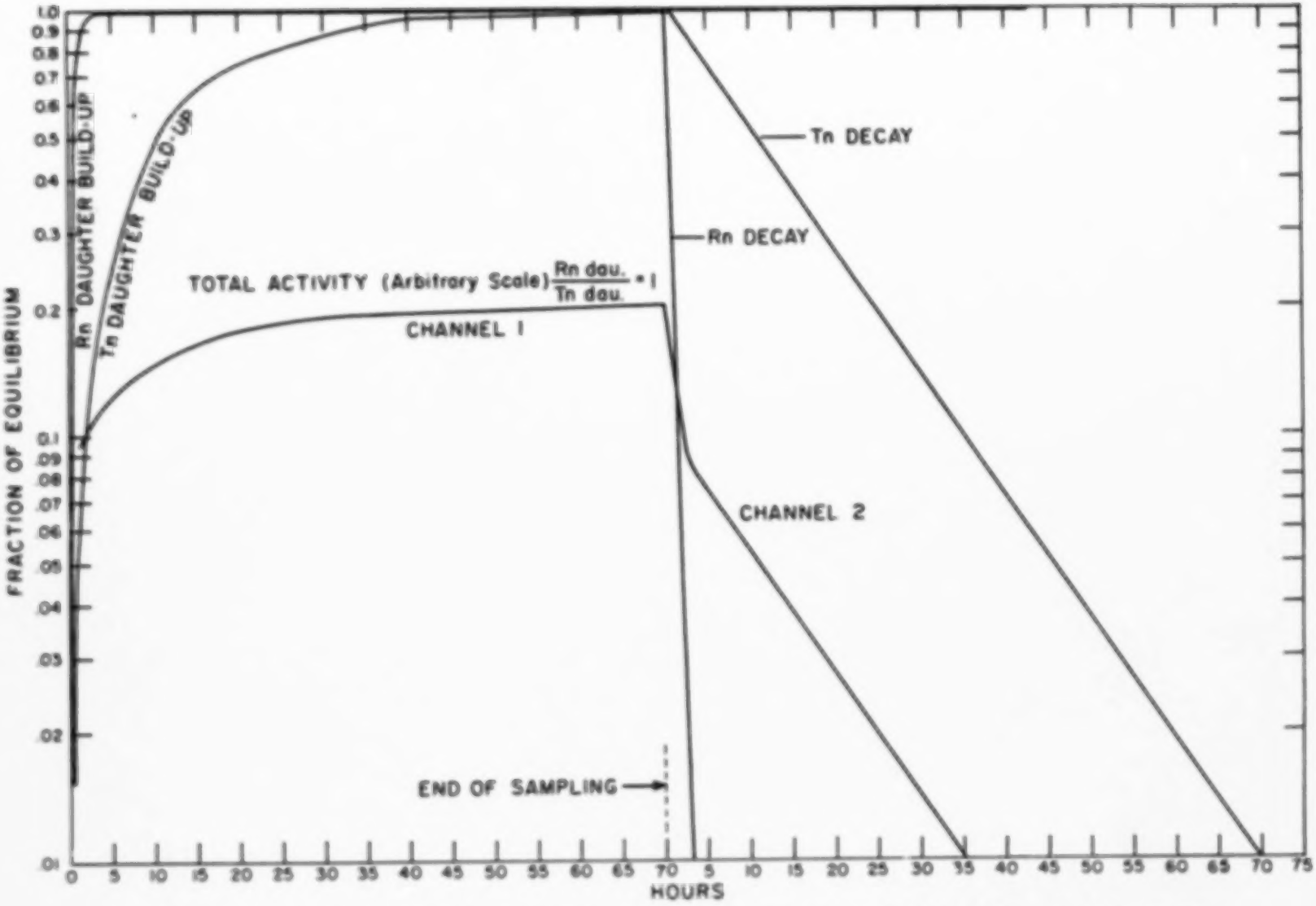
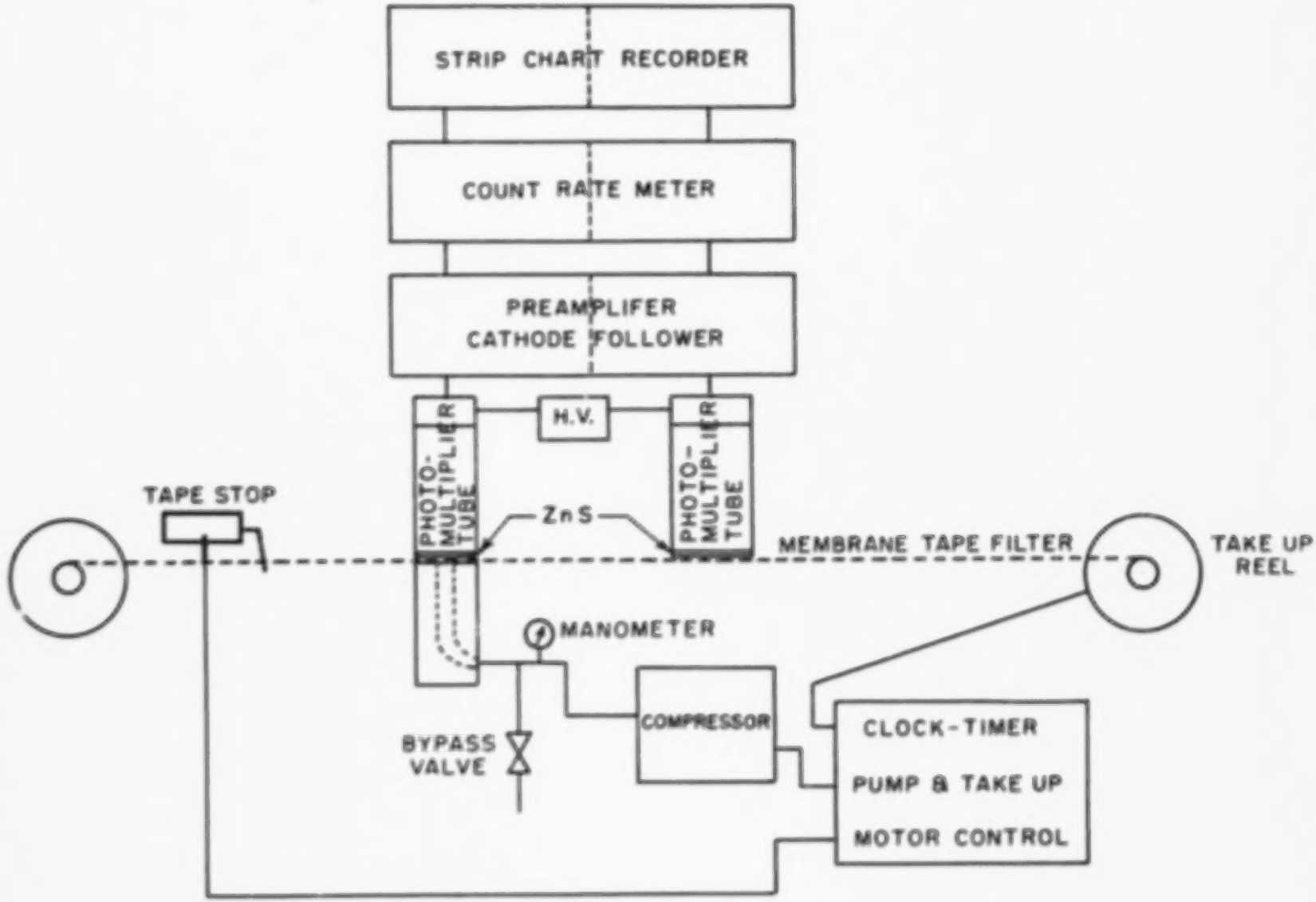


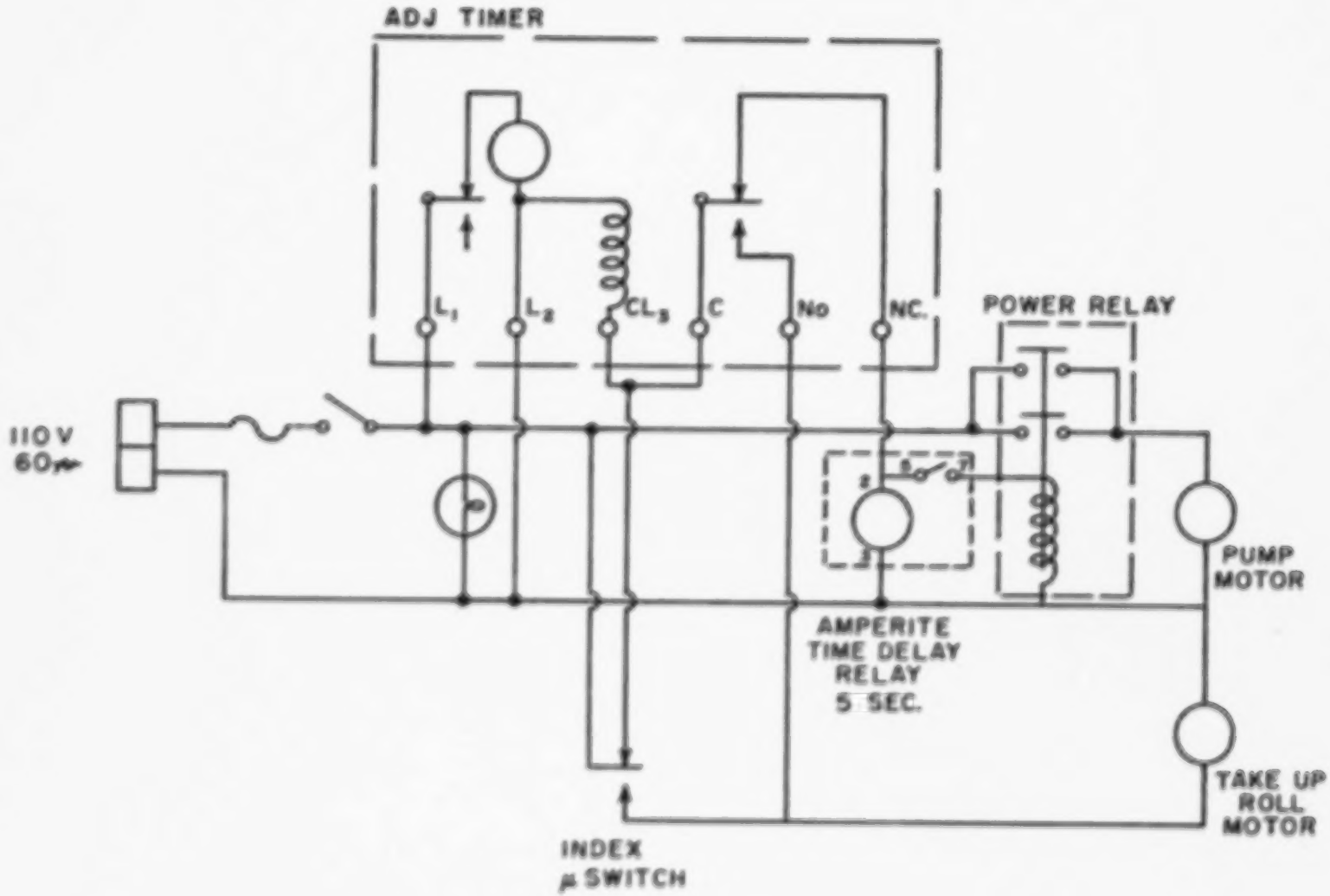
BUILD-UP AND DECAY OF RADON AND THORON DAUGHTERS ON FILTER

FIGURE 2



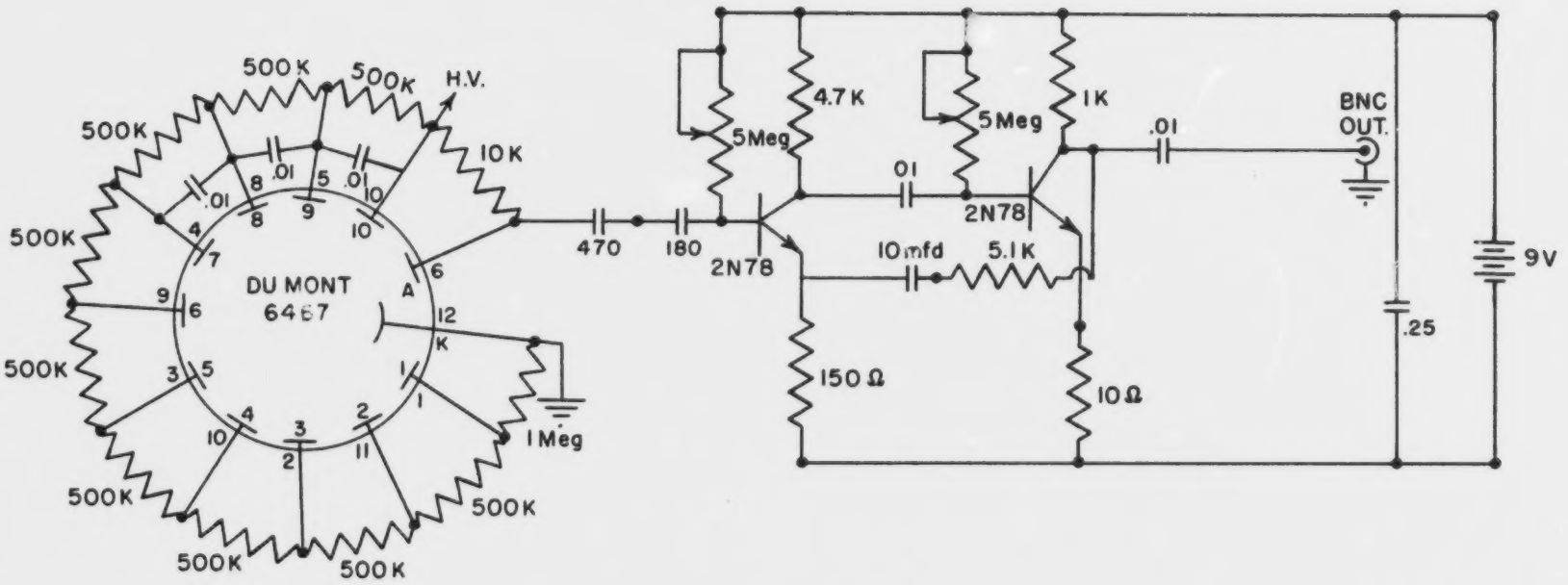
BLOCK DIAGRAM

FIGURE 3



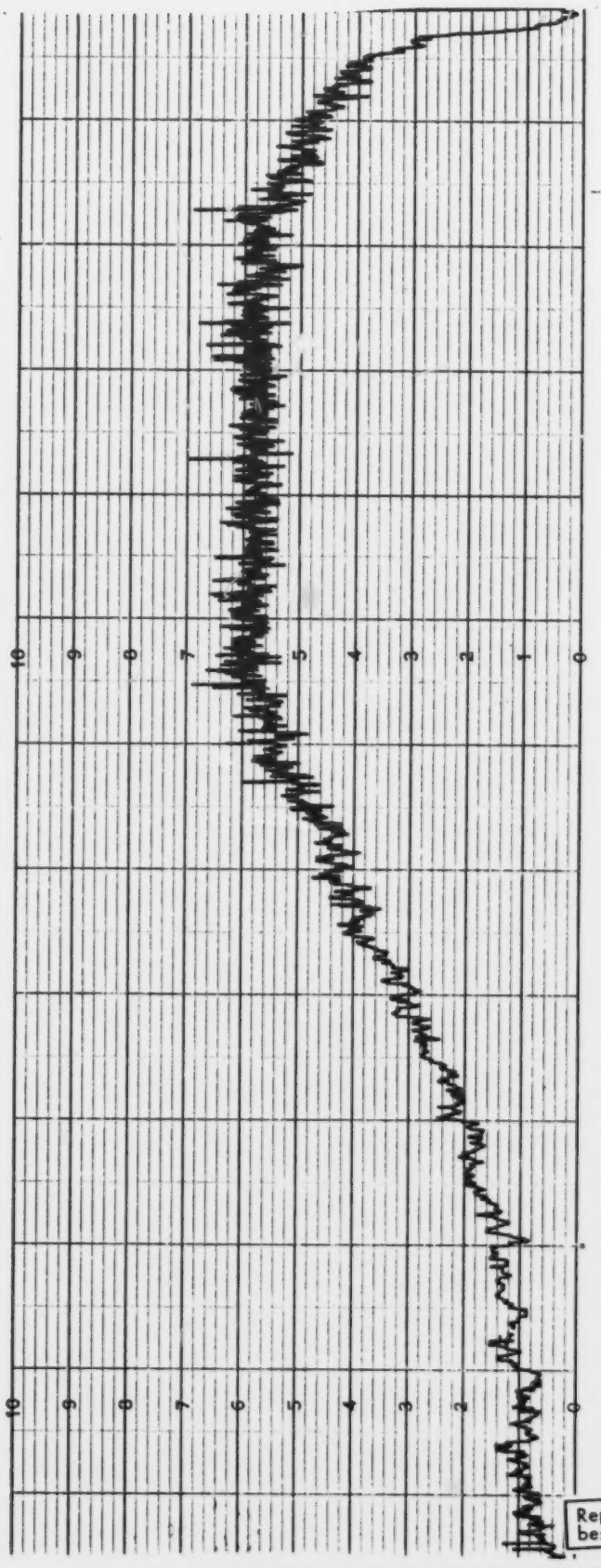
SAMPLE TIMER

FIGURE 4



PHOTOMULTIPLIER AND PREAMPLIFIER

FIGURE 5



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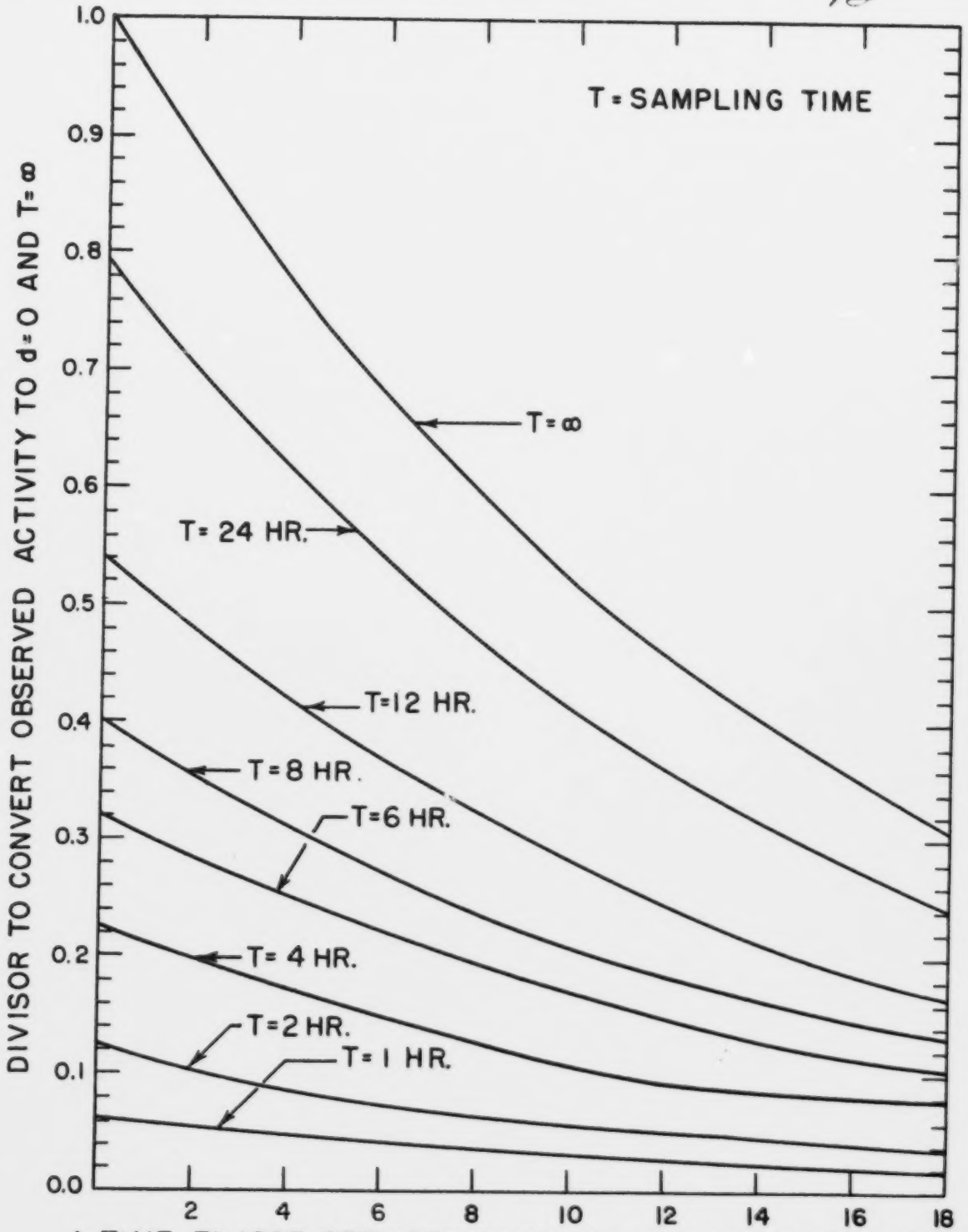

CONVERSION CHART—THORON DAUGHTER PRODUCTS

FIGURE 7